system 80 applies a charge to the stream of material 70. As each sphere 72 is formed and breaks from the stream 70, each sphere 72 retains a portion of the charge. As the charged spheres 72 descend, the spheres pass through or adjacent the charging plates 112 and 114 of the deflection means 110.

When the charging or repelling surfaces 112' and 114' are held at a predetermined desired voltage, the electrical field generated in the opening 118 provides a further charge to the spheres 72. The spheres 72 remain a predetermined distance from each other and from the charging or repelling surfaces 112' and 114'. This repelling force is generally shown by the arrows in FIG. 2. As each sphere 72 descends, the leading sphere is repelled, not only from succeeding spheres 72, but is also repelled from the sides of the charging surfaces 112' and 114', thereby preventing the like charged spheres from merging with each other.

It is to be understood that various suitable materials can be used, depending upon the end use application of the spheres to be formed. The actual charge on the sphere is a function, not only of the type of metal used, but also the diameter of the spheres, and the voltage between the charging plates 112 and 114 and the spheres 72. A charge on the sphere 72 in the order of 10^{-7} coulmb-gram is useful; however, it is to be understood that other charges are also useful and that the charges depend on the various parameters discussed above.

The charged spheres 72 solidify during the descent through the gaseous environment 102 and are completely solidified before contact with the liquid environment 122. As seen in FIG. 2, the spheres 72 first form a skin portion 172 which shields a molten portion 174. As the spheres 72 descend and solidify, the skin portion 172 thickens until the molten portion 174 disappears prior to contact of the sphere 72 with the funnel 124.

It is to be further understood that the sphere forming apparatus 10 of the present invention is operatively connected to a data acquisition/control system 180 to collect and measure data and to control the sphere forming apparatus. The data acquisition/control system 180 also measures the voltage output of the thermocouples and pressure transducers. The data acquisition/control system 180 is also operatively connected to the visual observation system 98 to provide the capability of actively controlling the formation of the spheres. During operation of the apparatus 10, the size and shape of the spheres being generated are measured. The data acquisition/control system 180 varies the crucible pressure and frequency generated by the stimulation actuator means 50 so that the sphere size and shape are kept at a predetermined desired diameter.

It is to be understood that only the preferred embodiments of the invention have been described and the numerous substitutions, modifications and alternations are permissible without departing from the spirit and scope of the invention as defined in the following claims.

We claim:

1. A method for forming and solidifying uniform sized and shaped solid spheres comprising the steps of:

providing a supply of a low viscosity liquid material in a crucible,

applying a minute periodic disturbance to the low viscosity liquid material in the crucible,

applying a pressure to the low viscosity liquid material, the pressure forcing the material through at least one orifice in the crucible as a steady laminar stream, the stream of the material exiting into an enclosed con-

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trolled low temperature solidification environment having a temperature of less than about 0° C., the enclosed controlled low temperature solidification environment containing at least one heat transfer medium, the heat transfer medium forming a heat gradient within the enclosed controlled low temperature solidification environment;

applying a charge to the stream of material as the stream exits the orifice and breaks up into a plurality of uniform sized and shaped liquid spheres,

passing the charged liquid spheres through an electric field to deflect the liquid spheres, and

allowing the liquid spheres to pass through the heat transfer medium in the enclosed controlled low temperature solidification environment to cool and solidify into the uniform sized and shaped solid spheres.

2. The method of claim 1, in which the enclosed controlled temperature solidification environment includes a first, gaseous environment through which the charged spheres are passed, the first, gaseous environment containing the first heat transfer medium which comprises a spray of cooling fluid, liquefied gas or halo-carbon which evaporates in the enclosed controlled temperature solidification environment and which absorbs the heat of fusion from the spheres.

3. The method of claim 2, in which the enclosed controlled temperature solidification environment includes a second, liquid environment through which the spheres pass after passing through the first, gaseous environment; the second, liquid environment containing a second heat transfer medium which comprises a supply of a liquid material.

4. The method of claim 3, comprising passing the spheres through the second, liquid environment to remove heat from the spheres and to cushion the spheres before the spheres contact a bottom of the enclosed controlled temperature solidification environment.

5. The method of claim 3, comprising varying a distance defined between a point at which the stream breaks into the spheres and a point at which the spheres contact the second or liquid environment.

6. The method of claim 1, further including the step of visually monitoring the stream of low viscosity liquid material as the stream breaks into spheres to provide information on the diameter and shape of the spheres and the stability of the stream.

7. The method of claim 1, comprising collecting the solidified spheres in a funnel-shaped bottom of the enclosed controlled temperature solidification environment.

8. The method of claim 1, in which the solid spheres have a diameter ranging from about 12 to about 1000 microns.

9. The method of claim 1, in which the spheres pass through the enclosed controlled temperature solidification environment for about 0.5 to about 1.5 seconds prior to contacting a bottom of the enclosed controlled temperature solidification environment.

10. The method of claim 1, comprising applying the minute periodic disturbance to the low viscosity liquid material by a piezoelectric actuator.

11. The method of claim 10, in which the piezoelectric actuator comprises a stack of piezoelectric crystals mounted on a top portion of the crucible.

12. The method of claim 1, comprising applying the minute periodic disturbance to the low viscosity liquid material by an electromechanical transducer mounted on a top portion of the crucible.

13. The method of claim 1, comprising applying the minute periodic disturbance with a nozzle that has a fixed aspect ratio defining the orifice.

14. The method of claim 1, comprising applying a substantially constant positive pressure to the low viscosity liquid material to force the low viscosity liquid material out through the orifice in a steady laminar stream.

15. The method of claim 1, in which the deflection means comprises two spatially separated surfaces and comprising generating the electrical field between the two surfaces to deflect the descending spheres.

16. A method for forming uniform sized and shaped spheres comprising the steps of:

providing a supply of a low viscosity liquid material in a crucible,

applying a minute periodic disturbance to the low viscosity liquid material in the crucible,

applying a pressure to the low viscosity liquid material, the pressure forcing the material through at least one orifice in the crucible as a steady laminar stream, the stream of the material exiting into an enclosed controlled temperature solidification environment;

applying a charge to the stream of material as the stream exits the orifice and breaks up into a plurality of uniform sized and shaped liquid spheres;

passing the charged liquid spheres through an electric field to deflect liquid the spheres; and

allowing the spheres to pass through first and second media in an enclosed controlled temperature solidification environment to cool and solidify the spheres;

the enclosed controlled temperature solidification environment including a first, gaseous environment through which the charged spheres are passed, the first, gaseous environment containing the first medium which comprises a spray of cooling fluid, liquefied gas or halocarbon, the first medium evaporating in the enclosed controlled temperature solidification environment and absorbing the heat of fusion from the spheres;

the enclosed controlled temperature solidification environment also including a second, liquid environment through which the spheres pass after passing through the first, gaseous environment, the second, liquid environment containing the second medium which comprises a supply of a liquid material, the second medium cushioning the spheres before the spheres contact a bottom of the enclosed controlled temperature solidification environment.

17. The method of claim 16, further including the step of visually monitoring the stream of low viscosity liquid material as the stream breaks into spheres to provide information on the diameter and shape of the spheres and the stability of the stream.

18. The method of claim 16, comprising collecting the solidified spheres in a funnel-shaped bottom of the enclosed controlled temperature solidification environment.

19. The method of claim 16, in which the spheres have a diameter ranging from about 12 to about 1000 microns.

20. The method of claim 16, in which the spheres pass through the enclosed controlled temperature solidification environment for about 0.5 to about 1.5 seconds prior to contacting a bottom of the enclosed controlled temperature solidification environment.

21. The method of claim 16, in which the enclosed low temperature solidification environment is at a temperature of less than about 0° C.

22. The method of claim 16, comprising varying a distance defined between a point at which the stream breaks into the spheres and a point at which the spheres contact the second, liquid environment.

23. The method of claim 16, comprising applying the minute periodic disturbance to the low viscosity liquid material by a piezoelectric actuator.

24. The method of claim 23, in which the piezoelectric actuator comprises a stack of piezoelectric crystals mounted on a top portion of the crucible.

25. The method of claim 16, comprising applying the minute periodic disturbance to the low viscosity liquid material by an electromechanical transducer mounted on a top portion of the crucible.

26. The method of claim 16, comprising applying the minute periodic disturbance with a nozzle that has a fixed aspect ratio defining the orifice.

27. The method of claim 16, comprising applying a substantially constant positive pressure to the low viscosity liquid material to force the low viscosity liquid material out through the orifice in a steady laminar stream.

28. The method of claim 16, in which the deflection means comprises two spatially separated surfaces and comprising generating the electrical field between the two surfaces to deflect the descending spheres.

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